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ABSTRACT

The "learning cycle" is not a teaching method but rather a teaching procedure that allows for many methods of teaching. If teacher preparation courses are organized and delivered as learning cycles, then preservice teachers will discover that the learning cycle is an instructional model that: (1) allows science to be taught as it is structured; (2) implements the recommendations of the National Science Education Standards; and (3) reflects current constructivist learning theories. This paper describes four science education courses for preservice teachers, two for elementary education majors and two for secondary education majors. (Contains 13 references.) (WRM)

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LITERACY THROUGH THE LEARNING CYCLE

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What is the nature of science? What are the national standards for science education? What is the nature of human learning? What teaching procedure matches the nature of science, the national standards for science education, and the nature of human learning? Addressing these questions has guided us in the development and maintenance of a theory-based program for preparing science teachers for the 21st century. The primary components of a theory-based, teacher education program in science education are fourfold.

Science is the quest for knowledge. Such a description infers the processes and products of science and that science should be experienced by students as it is practiced by scientists.

National Science Education Standards (NSES) is a comprehensive guide for translating the processes and products of science into the preparation of 1) scientifically literate students; 2) teachers with theoretical and practical knowledge about science, learning, and science teaching; 3) sound assessment strategies; and 4) developmentally appropriate science content.

Learning is constructing knowledge from experiences. This tenet is central to the cognitive developmental model of Piaget and is the derivative for the learning cycle.

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The *Learning Cycle* is a teaching procedure that 1) parallels the nature of science, 2) applies the NSES, and 3) translates a model of cognitive development. Our expansion of the learning cycle has resulted in a version of that teaching procedure which includes social/psychological models of Vygotsky and Ausubel.

The learning cycle is *not* a teaching *method*. The learning cycle is a teaching *procedure* which allows for many methods of teaching (e.g., laboratory experiments, questioning strategies, demonstrations, group work, field trips, the use of modern technologies). All of these common science teaching methodologies can be used within the three phases of the learning cycle--*exploring concepts, naming concepts, and expanding concepts.*

How and when can the theory-base components be introduced and developed in science "methods" courses? If teacher-preparation ("methods") courses are organized and delivered as learning cycles, then the preservice teachers discover that the learning cycle is an instructional model that 1) allows science to be taught as it is structured, 2) implements the recommendations of the National Science Education Standards, and 3) reflects current constructivist learning theories.

Four science education courses serve as vehicles for our students as they prepare to teach science, two for elementary education majors and two for secondary education majors, respectively: EDSC 4093 Inquiry Based Science Teaching, EDSC 4193 Teaching Science in the Elementary Schools, EDSC 4513 Teaching Science in the Secondary Schools, and EDSC 5514.

Science Curricula Implementation in the Secondary Schools. Within these courses--and student teaching--our preservice teachers explore seven fundamental questions as they prepare to teach science.

1. What is the nature of science and science teaching?
2. What are the goals of science education?
3. What is the nature of the learner?
4. What are the relationships among the nature of the science, science teaching, the goals of science and the nature of the learner, i.e. the theory base of school science?
5. How do we develop learning cycles?
6. How are various methods and technologies used within the learning cycle?
7. What is an authentic assessment plan for theory based school science?

The Nature of Science and Science Teaching

We begin the methods courses by asking our students (preservice science teachers) to construct their own ideas about the nature of science. We ask them to describe or define science, first individually and then collaboratively in small groups. Their definitions are compared to those of known scientists such as Albert Einstein, Niels Bohr, and Maria Mitchell. The students easily recognize that their descriptions of science closely match those of scientists. That is, the nature of science is to investigate through experiences and then to logically explain the data gained through those experiences. Science is not merely facts, laws, principles, and concepts but

rather the process of finding them. Our students gravitate to this simple and concise description of science provided by an historian of science, Duane Roller: Science is the quest for knowledge, not the knowledge itself"; but what is the nature of a quest?

Our students are now prepared to experience a teaching procedure consistent with their description of science, therefore we engage our students in a "model" learning cycle investigation. Following the investigation, our students (through class discussion) describe each phase of the learning cycle they have just experienced. We, the instructors, supply the learning cycle terminology which is descriptive of each phase of the learning cycle--exploration, term introduction, concept application (Marek and Cavallo, 1997). The term learning cycle is introduced as the name of the teaching procedure that the students just experienced. Students now describe how the learning cycle is consistent with their description of the nature of science. With their fundamental understandings of the relationship between the learning cycle and the nature of science, our students now expand their understandings by examining the goals and purposes of science education.

The Goals of Science Education

Students explore selected readings from The Central Purpose of American Education (EPC, 1961), Science for All Americans (AAAS, 1990), and the National Science Education Standards (NRC, 1996). By examining these documents, our students discover that the *central*

purpose of our educational system is the development of critical thinking abilities and that school activities should be designed to lead students toward this goal. Thinking abilities are defined in the EPC document as the rational powers of recalling, comparing, inferring, generalizing, deducing, classifying, analyzing, imagining, synthesizing, and evaluating. We engage our students in a variety of activities--learning cycles--that use and apply the rational powers. Following these activities, our students develop a table showing science experiences teachers can provide for their students that will incorporate the use of the rational powers and lead to the development of critical thinking abilities (Figure 1).

Science Process Activities	Rational Powers Used
Collecting Data Observing Describing Experimenting	Comparing, Inferring, Recalling
Organizing Data Making tables Graphing Grouping Serial ordering Classifying	Classifying, Analyzing, Recalling
Interpreting Data Looking for relationships Constructing meaning	Inferring, Comparing, Recalling
Generalizing from Data Discerning a pattern Summarizing and proposing a trend Drawing a conclusion	Inferring, Generalizing, Synthesizing, Recalling
Explaining Generalizations from Data	Imagining, Inferring, Recalling, Synthesizing, Evaluating

Making a model Creating or formulating a concept or idea Presenting data and conclusions to others	
Predicting from Models or Patterns Deducing from a generalization Forming a hypothesis Testing a hypothesis, generalization or model	Deducing, Inferring, Recalling, Synthesizing, Evaluating
The Development of Logical Thinking	

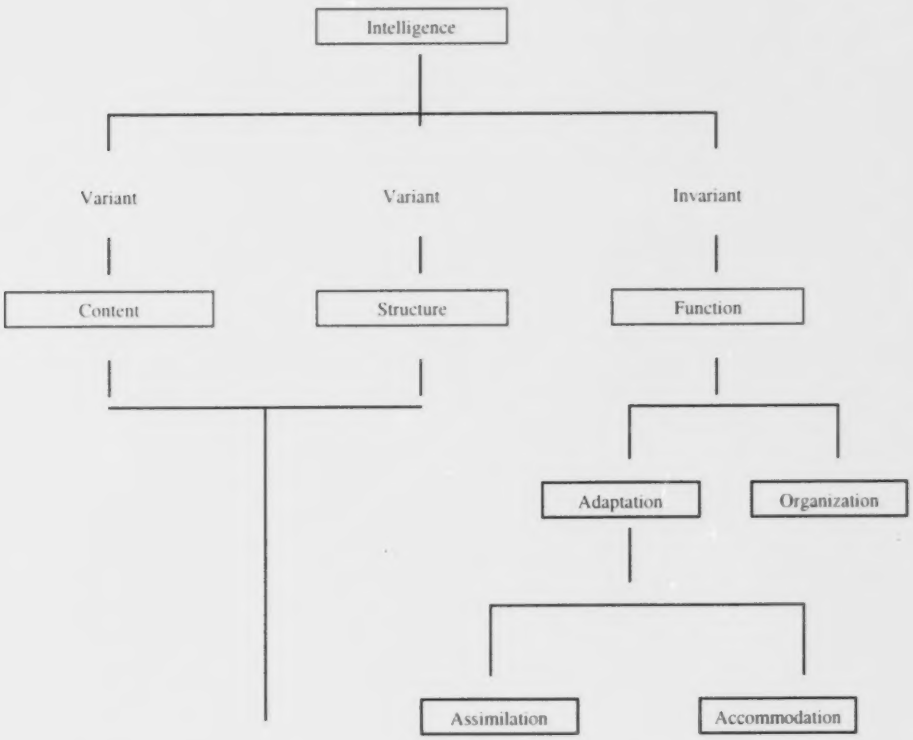
Figure 1. The rational powers used in science process activities to develop logical thinking (adapted from Renner, 1985)

(Figure 1 is FIG. 2-6 from the textbook, Marek, E.A., & Cavallo, A.M.L. 1997. The Learning Cycle: Elementary School Science and Beyond. Portsmouth, NH: Heinemann.)

The Nature of the Learner

Our students begin to develop a model of cognitive development--learning--by gathering data from children and adolescents. Our preservice teachers interview students in area schools using an array of tasks. For example, the elementary education majors interview elementary school children using Piagetian Conservation Tasks while the secondary, science education majors use the Test of Logical Thinking (TOLT) with middle and high school students. These data are then used to construct the Piagetian "stages" model. Our students begin to develop understandings of preoperational thought, concrete (intuitive) thought processes and formal

(reflective) operations. From this developmental stages model, our preservice teachers construct a model of intelligence as depicted in Figure 2. This is our representation of a model of intelligence; our students are assigned the task of developing their own models or representations of the nature of human learning. These models and essays are used to assess students' understandings of Piaget's model of intelligence.



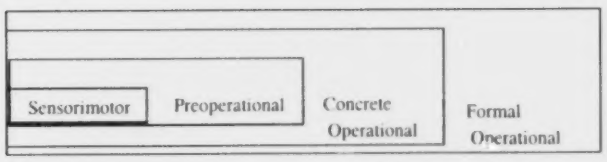


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Figure 2. An interpretation of the relationships within Piaget's model of intelligence

(Figure 2 is FIG. 3-10 from the textbook, Marek, E.A., & Cavallo, A.M.L. 1997. The Learning Cycle: Elementary School Science and Beyond. Portsmouth, NH: Heinemann.)

The Theory Base of School Science

At this point in our students' preparation for science teaching, they have developed understandings of the nature of science and science teaching, the goals of science education, and the nature of human learning. The next logical question: What are the relationships among these elements? For example the learning cycle was derived from the mental functioning model defined as assimilation>disequilibration>accommodation>organization. One way of depicting the relationship between the phases of the learning cycle and mental functioning can be seen in Figure 3.

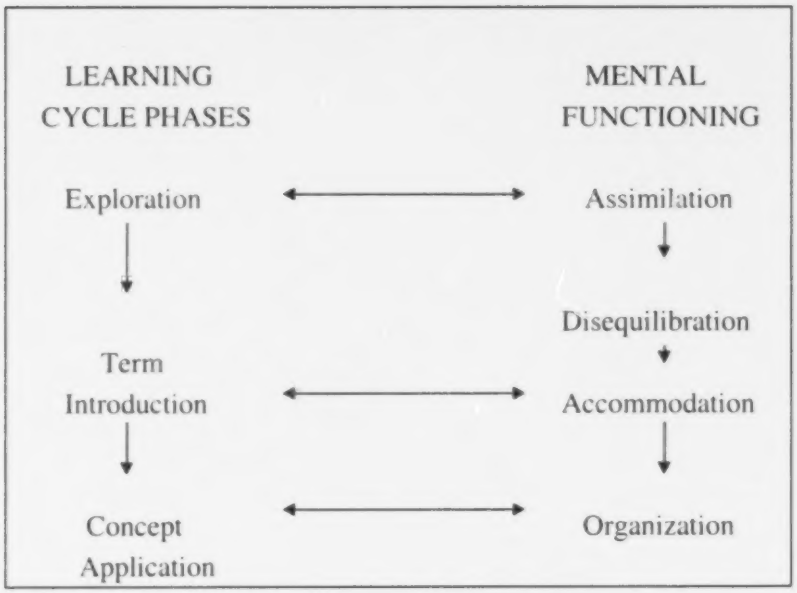

Figure 3. The learning cycle and Piaget's model of mental functioning

(Figure 3 is FIG. 4-1 from the textbook, Marek, E.A., & Cavallo, A.M.L. 1997. The Learning Cycle: Elementary School Science and Beyond. Portsmouth, NH: Heinemann.)

Although originally based on Piagetian theory, the learning cycle also embodies other constructivist paradigms of learning and development. These paradigms include social constructivist theory (Vygotsky, 1978) and meaningful learning theory (Ausubel, 1963). Our preservice teachers engage in a variety of activities in which they examine how these paradigms are embedded in the learning cycle.

Consistent with social constructivist theory, the preservice teachers discover that *scaffolding* is used throughout the learning cycle. Scaffolding occurs as classroom teachers use

questions, models, analogies and clues to help their students interpret data and form understandings of concepts. In the learning cycle, classroom teachers work within each students *zone of proximal development* toward attaining new levels of development.

Through our modeling of the learning cycle, preservice teachers become immersed in the *scientific subculture* as they make observations, collect data, discuss and interpret findings, state concepts and apply concepts. Such experiences help them recognize that by engaging in learning cycles, their future students will become adept at the language and thinking processes of science, and therefore members of this unique discourse community.

The preservice teachers also discover the relevance of meaningful learning in the learning cycle, particularly when they experience, and later develop, application (expansion) activities. They discover how learning cycles fulfill the three criteria of meaningful learning by providing application activities *(meaningful learning tasks)* that help students link their understanding of the concept *(relevant prior knowledge)* to other experiences in science and in everyday life (Ausubel, 1963; Novak, 1988). Since students are active in the learning process *(meaningful learning set)*, the learning cycle promotes the use of students' meaningful learning strategies as opposed to rote strategies.

Our students are at a crucial point in their learning about theory based school science; therefore they are asked to prepare and compare concept maps. Their concept maps link the learning cycle with: the nature of science, purpose and goals of science education, and theories

of learning and development. The thinking and dialogue involved in constructing these maps helps our teachers meaningfully understand the theoretical and practical underpinnings of the learning cycle. We are now prepared to develop learning cycles.

Developing Learning Cycles

The preservice teachers have access to our large collection of learning cycle and non-learning cycle curriculum materials, which are housed in the Science Education Center. The preservice teachers frequently review and use learning cycle based curricula in their field experiences (e.g., SCIS-3, FOSS, Investigations in Natural Science, BSCS). However, our students also experience the challenge of developing original learning cycles. This process involves adapting learning cycles from non-learning cycle activities and materials. The preservice teachers construct teachers' and students' guides in complete and thorough form, then test their curricula in videotaped, peer teaching sessions within our courses. Using peer and instructor feedback, and their own self-reflections, they revise their learning cycles. The revised learning cycles are then field tested with students in the schools.

The preservice teachers also develop and teach learning cycles integrated with other subjects in the school curricula, and learning cycles in other disciplines such as mathematics, art and music. The teachers frequently present their original, field tested learning cycles at professional conferences, or submit them for publication.

Methods and Technologies Within the Learning Cycle

The learning cycle is not a teaching *method*. It is much greater in scope and philosophy than that. The learning cycle is a *teaching procedure* which, by design, allows for many

methods of teaching (e.g., questioning strategies, demonstrations, group work). For example, our students participate in a learning cycle in which questioning strategies are featured and emphasized. Students analyze the question types, cognitive load, and preplanned placement of questions throughout the lesson. In other learning cycles, technology is featured. In other words, students are involved in learning cycles which use slow motion, video imaging technology and measurements of pH using probes interfaced with computers. The key point is that different teaching methods and technologies are "compatible" and *necessary* within the learning cycle teaching procedure.

The learning cycles described here are conducted in the local schools by model teachers of science and this modeling is the vehicle for our students to gain direct experiences with various methods and technologies. *The model teachers are an essential and vital part of our teacher education program.*

The variety of methods and technologies used in learning cycles makes traditional forms of assessment inadequate. It is at this point in the "methods" courses that our students explore alternative forms of assessment for the learning cycle science classroom.

Assessment

The techniques we use to measure students' progress must *match* the form and nature of the instruction. Consequently, the use of authentic assessment is clearly consistent with the learning cycle teaching procedure. Such assessment may include conventional tests, but most often utilize alternative and innovative evaluation techniques. Most importantly, assessment must be streamed throughout learning cycles to measure students' progress *as learning occurs.* Our preservice teachers develop a variety of authentic assessments with their learning cycles. These assessments may include: journals or learning logs, concept maps, laboratory practical experiences, diagrams, three-dimensional models, analogies, oral presentations, poster presentations, teacher observations, oral quizzes, mental model or open-ended essays, and library research.

Summary

Our preservice teachers' science education courses are purposefully, of course, designed in learning cycles. That is, our students learn about the learning cycle by *engaging in learning cycles* about the theory-base and implementation of this teaching procedure. To match our teaching, we (the instructors) use authentic assessment, both as models for teachers, and to measure our students' progress as they learn about theory based school science.

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